fanjin

July 8, 2021

lets follow Fanjin a little more closely `/home/dan/usb_twitching/library/core/pnas_Wong_2011_slingshot_mo`
the purpose of this is to get a better understanding of analysing the trajectory so that we can fully understand how our simulated data differs from the experimental data

[1]:
```
import os
import sys
import collections
import numpy as np
import _fj
import matplotlib.pyplot as plt
import matplotlib as mpl
import command
import readtrack
import twanalyse
from tqdm import tqdm
```

[2]:
```
verbose = False
notename = 'fanjin'
notedir = 'fanjin/'
if not os.path.exists(notedir):
        os.makedirs(notedir)
join = os.path.join
def _savefig(name):
        d = os.path.dirname(name)
        if d:
                if not os.path.exists(d):
                        os.makedirs(d)
        save = join(notedir,name)
        print("saving to ", save)
        plt.savefig(save)
```

[3]:
```
# ------------------------------------------------------------
idx, ltrs = _fj.slicehelper.load_linearized_trs('all')
```

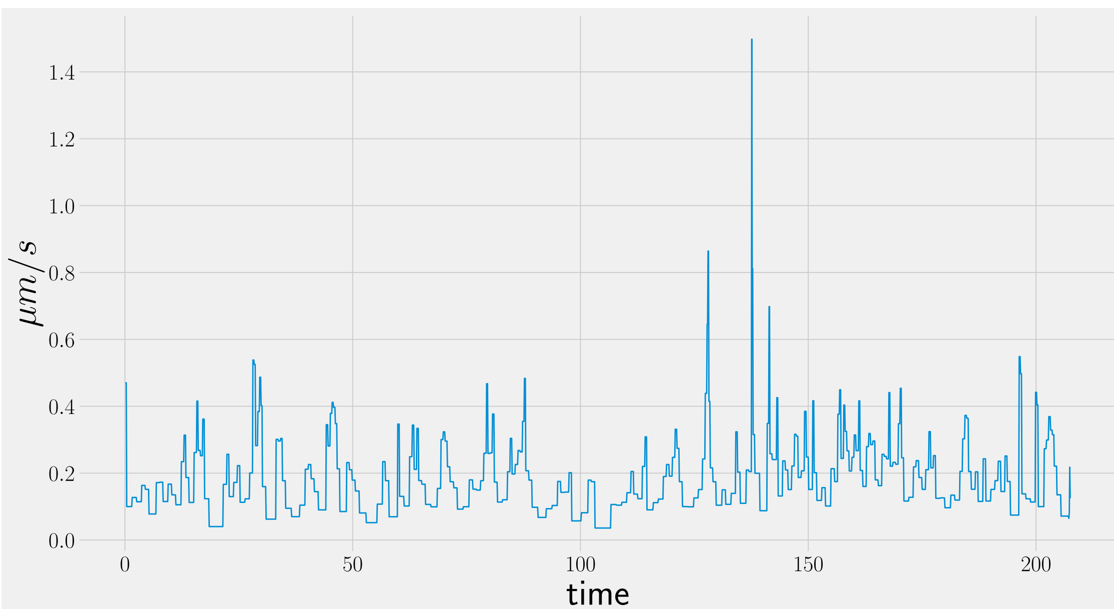
```
100%|      | 3113/3113 [00:01<00:00, 2709.50it/s]
```

[4]:
```
crawling_idx = _fj.slicehelper.load('default_crawling_list')
crawling = [ltrs[i] for i in crawling_idx]
```

```
candidate_idx = 2924
candidate = ltrs[candidate_idx]
whitelist = _fj.slicehelper.load('candidates_whitelist')
whitelist_tr = [ltrs[i] for i in whitelist]
# ------------------------------------------------------------
```

[5]:

```
# ------------------------------------------------------------
ax = plt.gca()
def plot_candidate(ax, track):
        time = track['time']
        velocity = track.get_head_v()
        track_speed = np.linalg.norm(velocity, axis=1)
        ax.plot(time[1:]-time[0], track_speed)
        ax.set_xlabel('time')
        ax.set_ylabel('$\mu m/s$')
# plot_candidate(ax, ltrs[10])
plot_candidate(ax, candidate)
plt.show()
```



these are linearised tracks, lets check that displacements add up to 0.12 μm

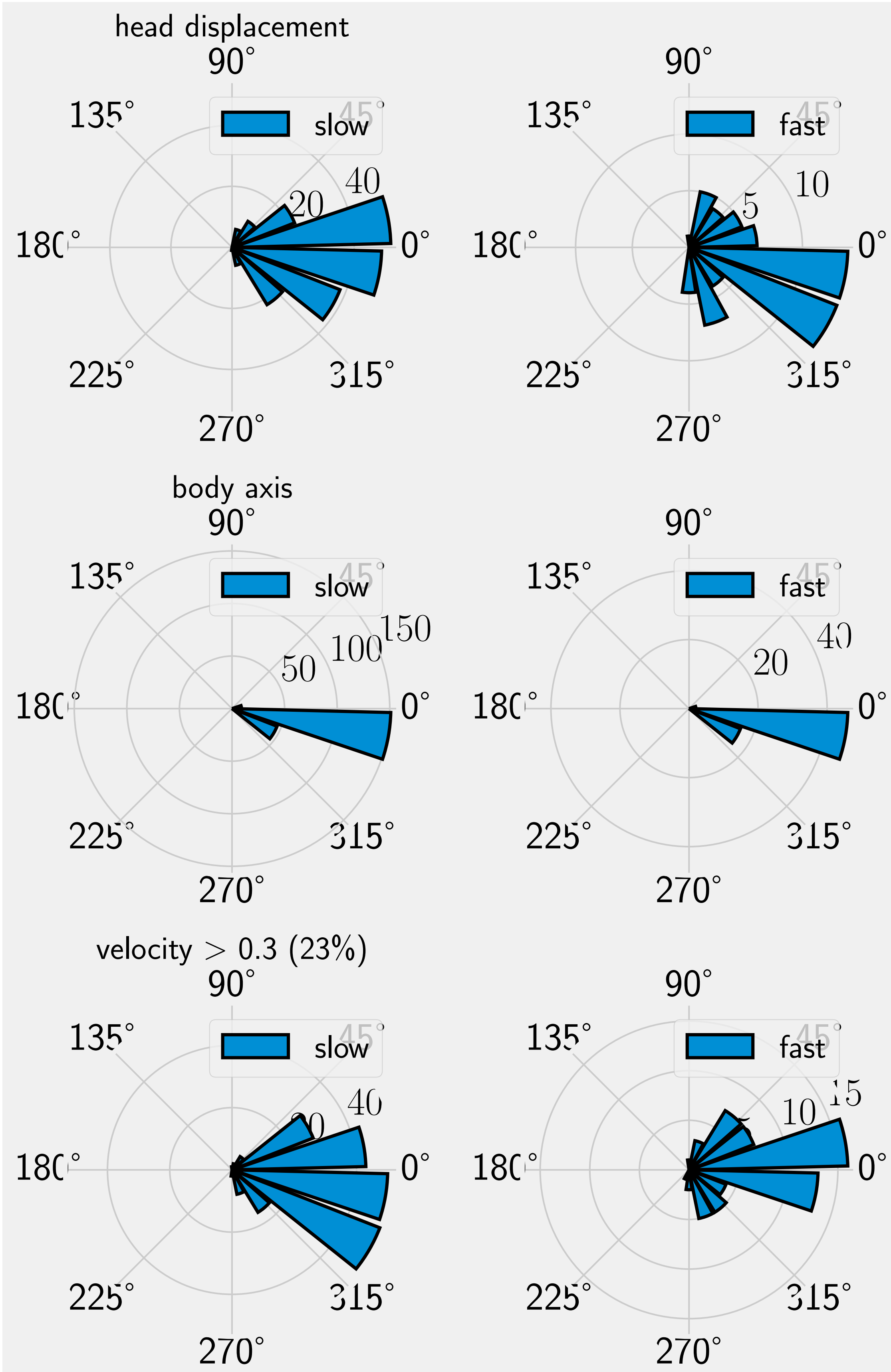
[6]:

```
# plot displacement angles, body axis angles
# for individual linearised trajectories

allpolar = twanalyse.allpolar
plotpolar = twanalyse.plotpolar
def plotpolar_with_axes(polardata):
```

```
        fig, axes = plt.subplots(3, 2, subplot_kw=dict(polar=True),
                figsize=(8,12))
        plotpolar(axes, polardata)
```

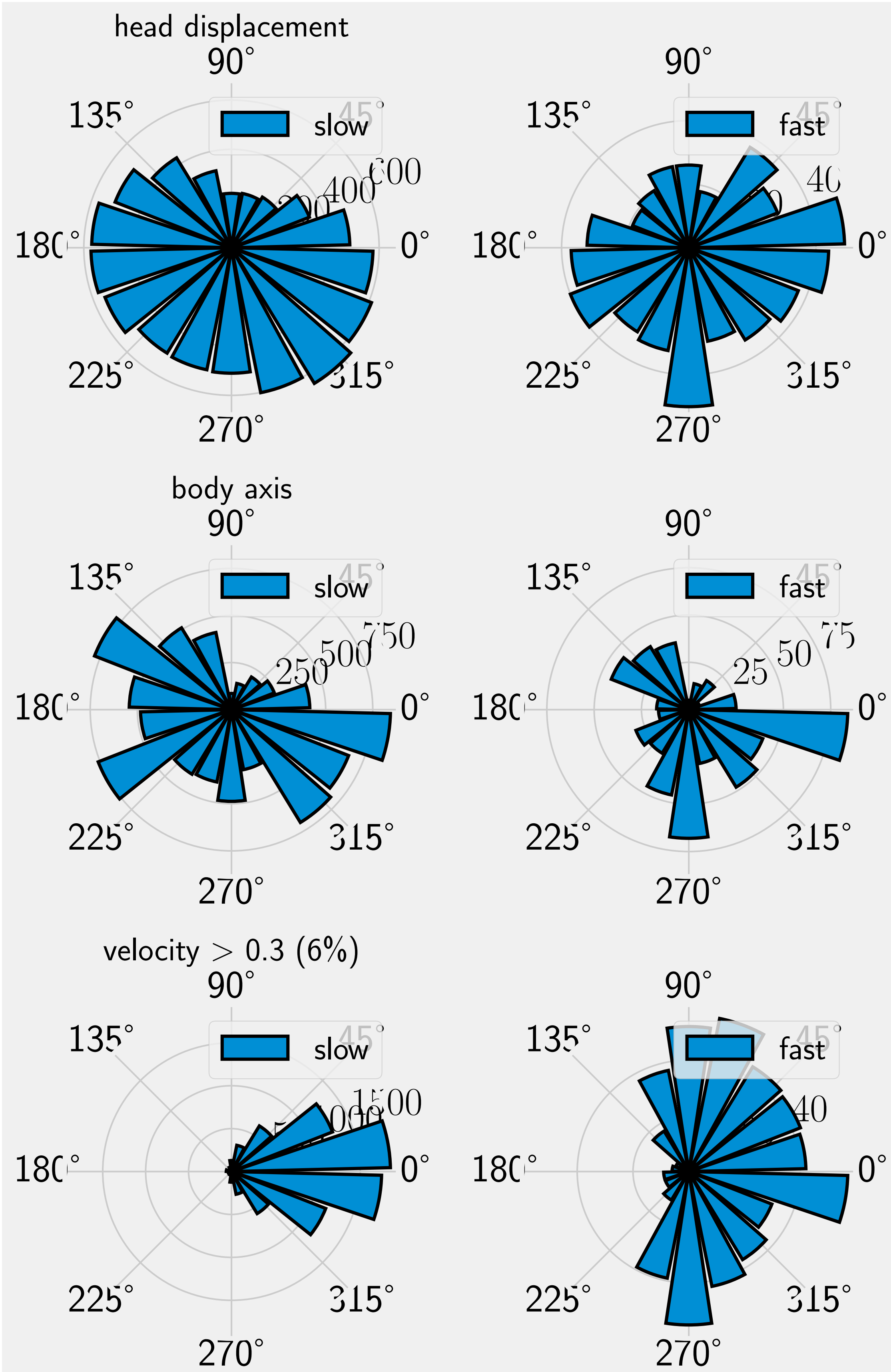
[7]:
```
# polar plots for the candidate track only
polardata = allpolar([candidate])
plotpolar_with_axes(polardata)
_savefig("polar_candidate.png")
```

```
100%|     | 1/1 [00:00<00:00, 1305.42it/s]
saving to  fanjin/polar_candidate.png
```


head displacement
90°
135°
45°
180°
0°
225°
315°
270°
slow
20
40
fast
5
10
body axis
slow
50
100
150
fast
20
40
velocity > 0.3 (23%)
slow
40
fast
10
15

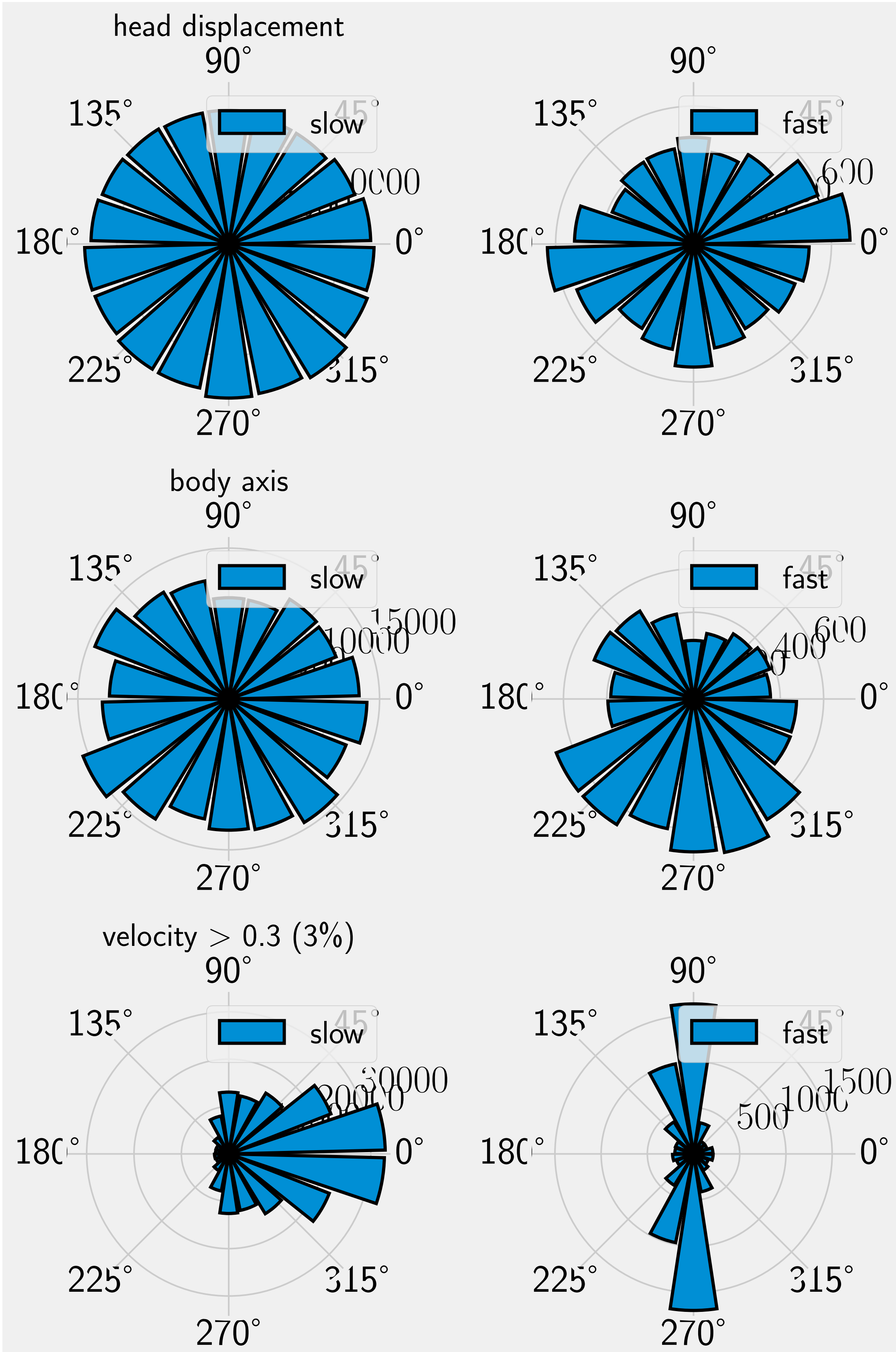
[8]:
```python
# polar plots for whitelist
polardata = allpolar(whitelist_tr)
plotpolar_with_axes(polardata)
_savefig("polar_whitelist.png")
```

```
100%|          | 64/64 [00:00<00:00, 3980.30it/s]
saving to  fanjin/polar_whitelist.png
```


head displacement
body axis
velocity > 0.3 (6%)
slow
fast
90°
135°
45°
180°
0°
225°
315°
270°

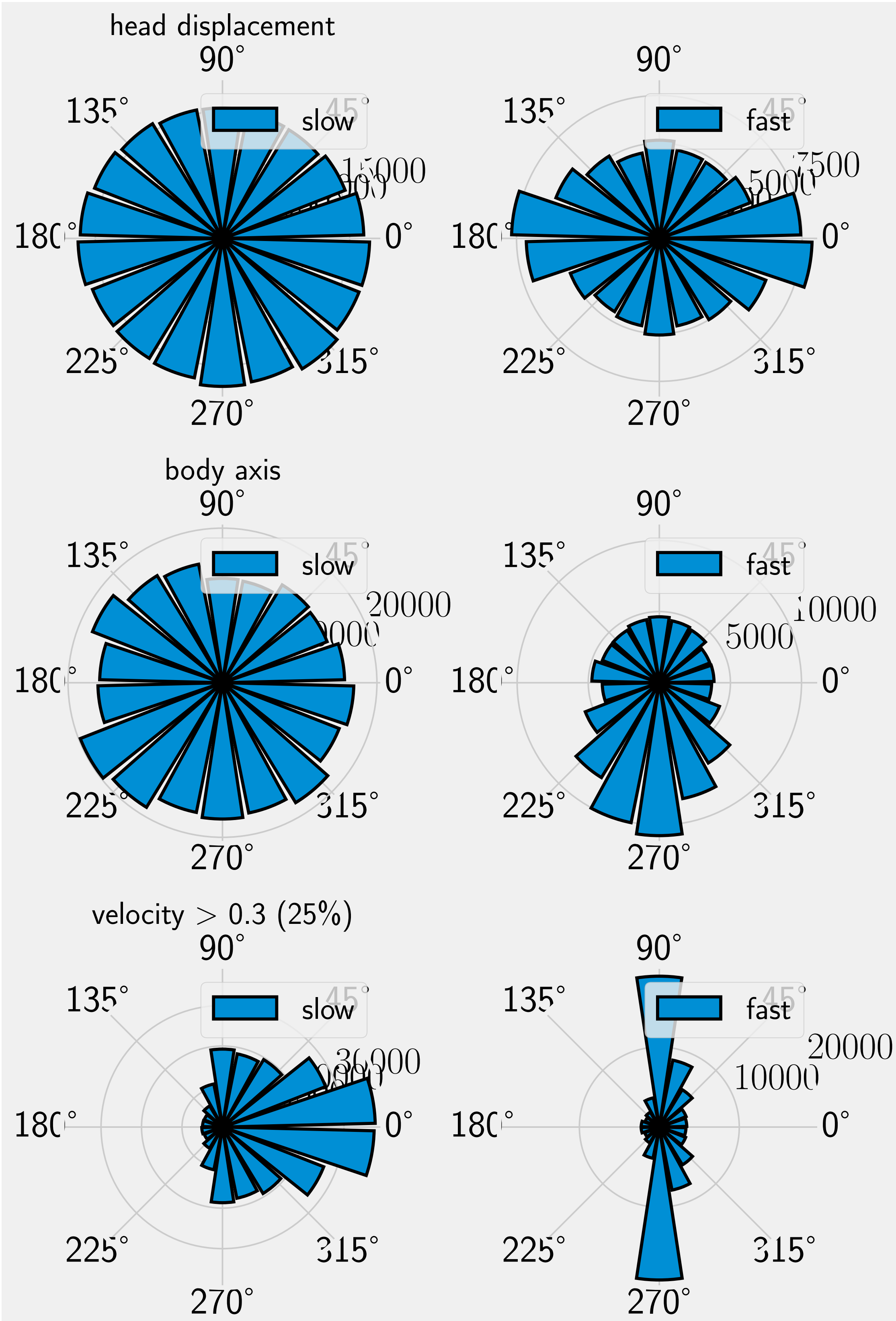
[9]:
```
# crawling data
polardata = allpolar(crawling)
plotpolar_with_axes(polardata)
_savefig("polar_crawling.png")
```

```
100%|          | 2505/2505 [00:00<00:00, 2880.64it/s]
saving to  fanjin/polar_crawling.png
```


head displacement
body axis
velocity > 0.3 (3%)
slow
fast
90°
135°
180°
225°
270°
315°
0°
45°

[10]:
```
# all data
polardata = allpolar(ltrs)
plotpolar_with_axes(polardata)
_savefig("polar_all.png")
```

```
  0%|          | 0/3113 [00:00<?,
?it/s]/home/dan/usb_twitching/pili/src/analysis/twanalyse.py:803:
RuntimeWarning: invalid value encountered in true_divide
  norm_dy = dy/np.linalg.norm(dy, axis=1)[:,np.newaxis]
100%|     | 3113/3113 [00:01<00:00, 2671.21it/s]
saving to  fanjin/polar_all.png
```


head displacement
body axis
velocity > 0.3 (25%)
slow
fast
90°
135°
45°
180°
0°
225°
270°
315°
15000
7500
5000
20000
10000
5000
30000
20000
10000

[11]:

```python
# velocity > 0.3 (25%) ???
# is this a bug in my code or due outliers in the 'all' data
# lets make a walking list with a mean velocity threshold (?)
# see localdir for the removed outliers
localdir = 'vel_outlier'

def velocity_outliers(idx, ltrs, minvel=0.0, maxvel=1.0):
        meanvel = np.array([np.mean(np.linalg.norm(ltr.
 ↪get_step_velocity(),axis=1)) for ltr in ltrs])
        print(np.isnan(meanvel).shape)
        print(idx.shape)
        nan_idx = idx[np.isnan(meanvel)]
        left_idx = idx[meanvel < minvel]
        right_idx = idx[meanvel > maxvel]
        return left_idx, right_idx, nan_idx

left, right, nan = velocity_outliers(idx, ltrs, maxvel=1.0)
bad_idx = np.union1d(right, nan)
l, r, n = left.size, right.size, nan.size
print('left\t{:4d}\tright{:4d}\tnan{:4d}'.format(l, r, n))
print('so there are {:d} candidates to remove'.format(bad_idx.size))

if verbose:
        import shapeplot
        for track_id in right:
                ltrack = ltrs[track_id]
                speed = np.linalg.norm(ltrack.get_step_velocity(), axis=1)
                print('fast step proportion', npcount(speed > 0.3)/speed.size)
                ax = plt.gca()
                shapeplot.longtracks(ax,[ltrack])
                name = join(localdir,'lt_{:04d}.png')
                _savefig(name.format(track_id))
                ax.clear()
        plt.close()

safeall = np.delete(idx, bad_idx)
```

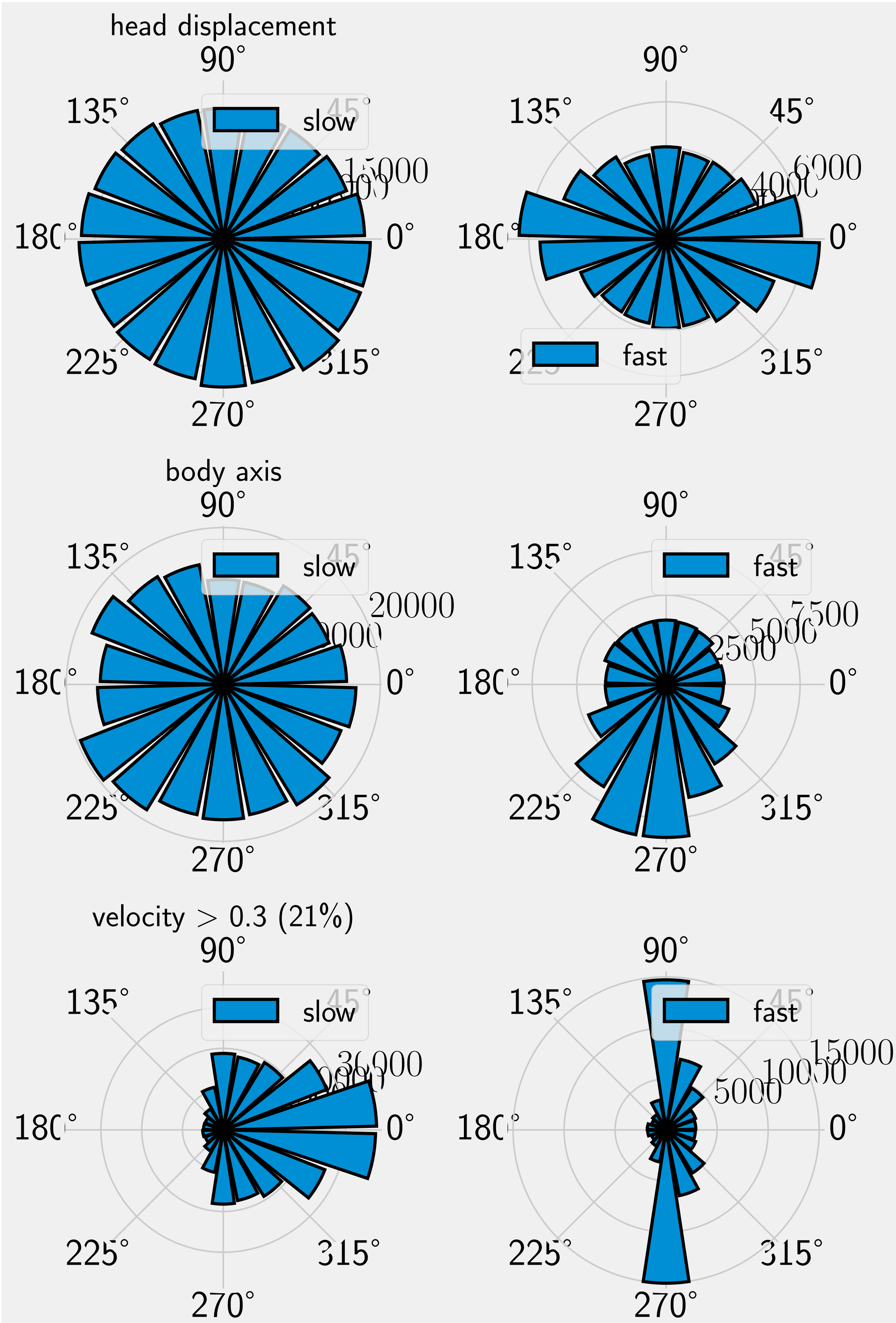
```
(3113,)
(3113,)
left       0    right  30       nan   6
so there are 36 candidates to remove
/home/dan/.local/lib/python3.8/site-packages/numpy/core/fromnumeric.py:3419:
RuntimeWarning: Mean of empty slice.
  return _methods._mean(a, axis=axis, dtype=dtype,
/home/dan/.local/lib/python3.8/site-packages/numpy/core/_methods.py:188:
RuntimeWarning: invalid value encountered in double_scalars
```

```
    ret = ret.dtype.type(ret / rcount)
```

[12]:

```
polardata = allpolar([ltrs[i] for i in safeall])
plotpolar_with_axes(polardata)
_savefig("polar_all.png")
# and the value did change from 25% to 21% but its still huge
# compared to the crawling set, need more work to see if
# high speed individuals in walking set are well resolved or not.
```

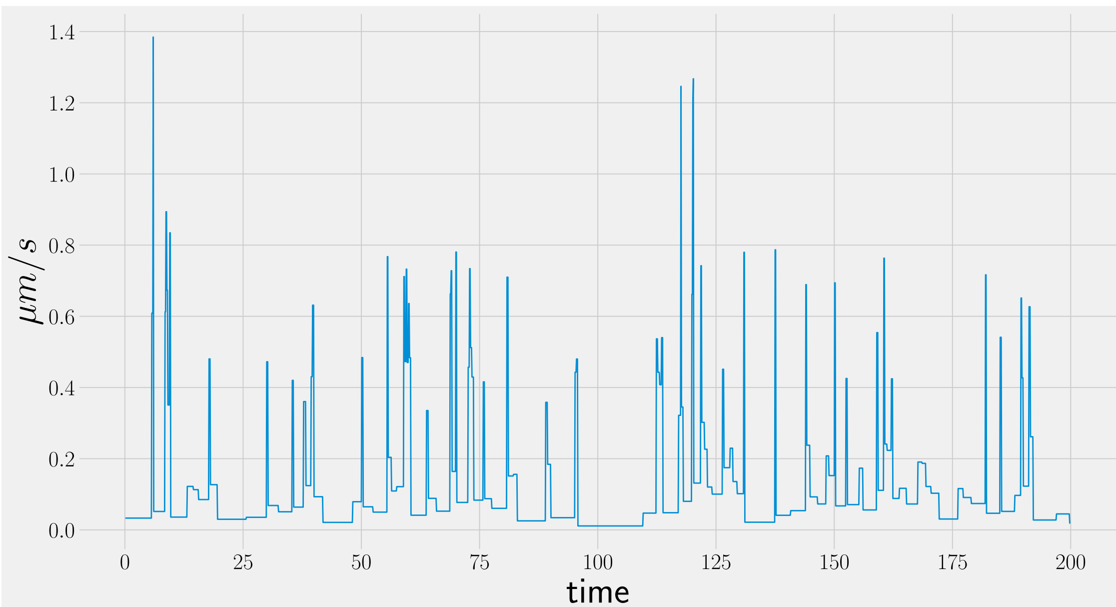
```
100%|      | 3077/3077 [00:01<00:00, 2943.91it/s]
saving to  fanjin/polar_all.png
```


head displacement
slow
fast
body axis
slow
fast
velocity > 0.3 (21%)
slow
fast

[13]:
```
# * candidate trajectory, all polar plots are oriented towards direction of␣
↪motion
# * whitelist, slow actions are polarised, fast actions have large components␣
↪in forward direction
#   and also at 90 degrees
# * all tracks, the deviation angle for the fast mode are now dominated by
#   90 degree rotations, so these are associated with slower moving trajectories
```

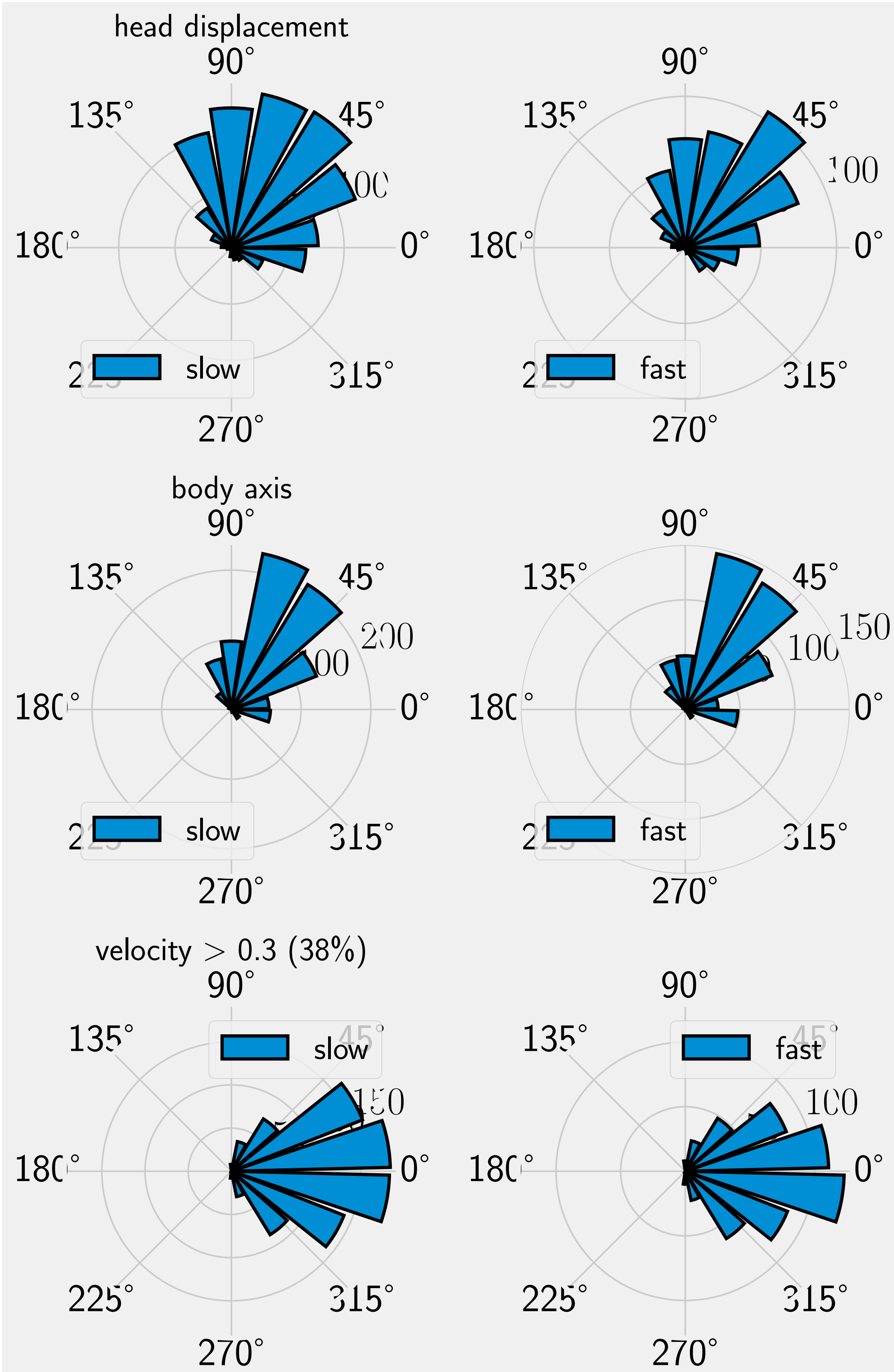
[14]:
```
# ------------------------------------------------------------
# lets do the same on simulation dataset
simdir = "/home/dan/usb_twitching/run/new/angle_smoothed/range_pbrf/
↪anchor_angle_smoothing_fraction_00.250"
with command.chdir(simdir):
        simtrs = readtrack.trackset()
sim_ltrs = [_fj.linearize(tr) for tr in simtrs]
simtr = sim_ltrs[0]

plot_candidate(plt.gca(), simtr.part(0,2000))
```

```
searching for tracks with form data/bacterium_*.dat
```



[15]:
```
# simulated data
polardata = allpolar(sim_ltrs)
plotpolar_with_axes(polardata)
```

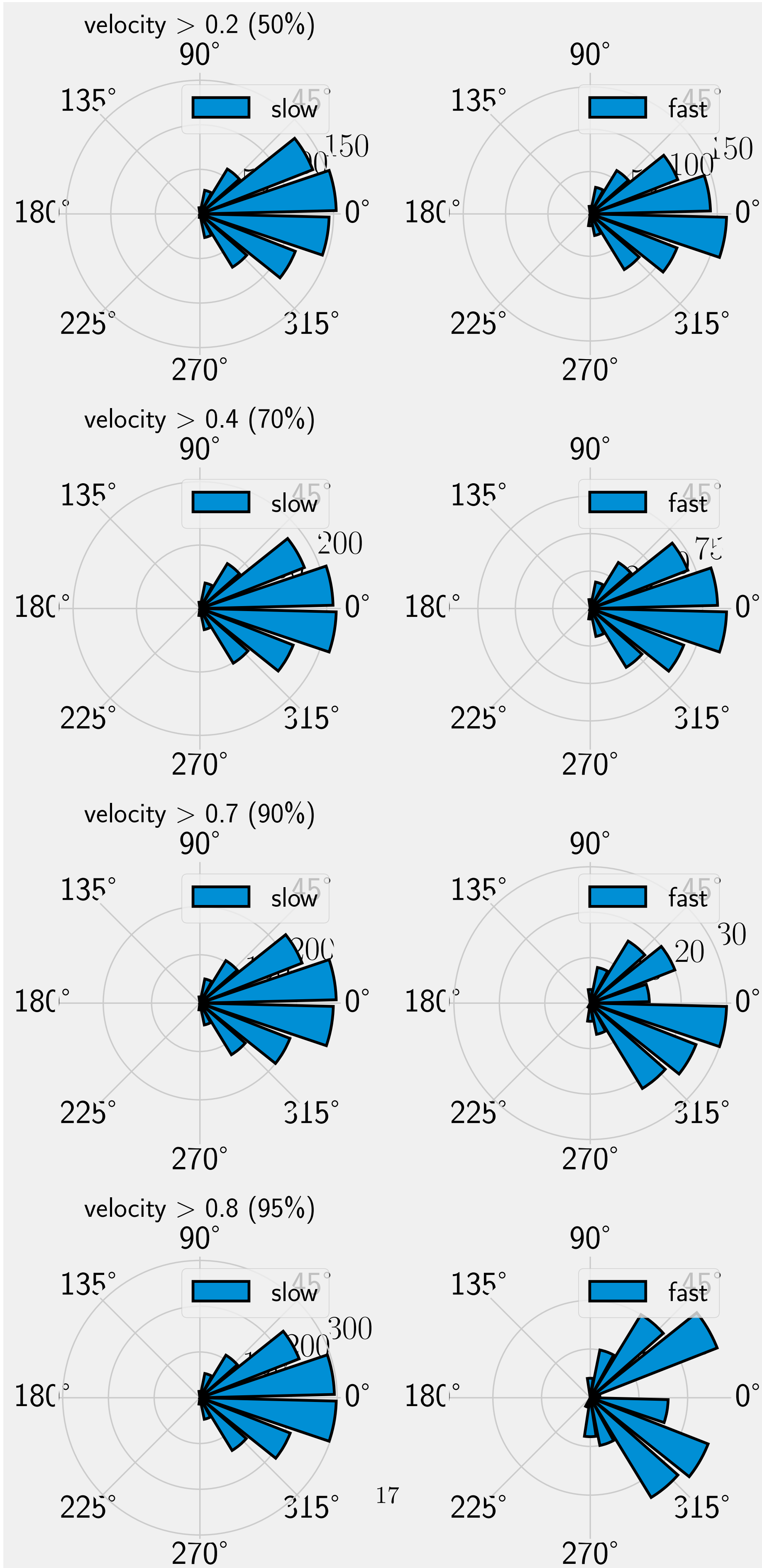
```
100%|      | 1/1 [00:00<00:00, 589.34it/s]
```


head displacement
body axis
velocity $>$ 0.3 (38%)
slow
fast
90°
45°
0°
135°
180°
315°
270°
225°
100
150
200

which is similar to candidate. but note that there is not much to distinguish fast and slow.

[16]:
```
# what about using a different velocity thresold?
# can we see a difference between fast and slow then?
vthreshold = 0.3
quantiles = [0.5, 0.7, 0.9, 0.95]
actdata = twanalyse.actions(sim_ltrs)
def fraction(x, threshold):
        npcount = np.count_nonzero
        return npcount(x>threshold)/x.size

N = len(quantiles)
fig, axes = plt.subplots(N, 2, subplot_kw=dict(polar=True),
        figsize=(8,4*N))
for i, q in enumerate(quantiles):
        quant = np.quantile(actdata['velocity'], q)
        row = axes[i]
        pdata = twanalyse.allpolar(sim_ltrs, quant)
        fastidx = actdata['velocity'] > quant
        twanalyse.polar_dev(row, pdata.deviation, fastidx)
        row[0].set_title(r'velocity $>$ {:3.1f} ({:d}\%)'.format(
                quant, int(100*q)
        ))
        plt.tight_layout()
```

```
100%|      | 1/1 [00:00<00:00, 1565.04it/s]
100%|      | 1/1 [00:00<00:00, 601.51it/s]
100%|      | 1/1 [00:00<00:00, 583.11it/s]
100%|      | 1/1 [00:00<00:00, 587.52it/s]
100%|      | 1/1 [00:00<00:00, 579.32it/s]
```

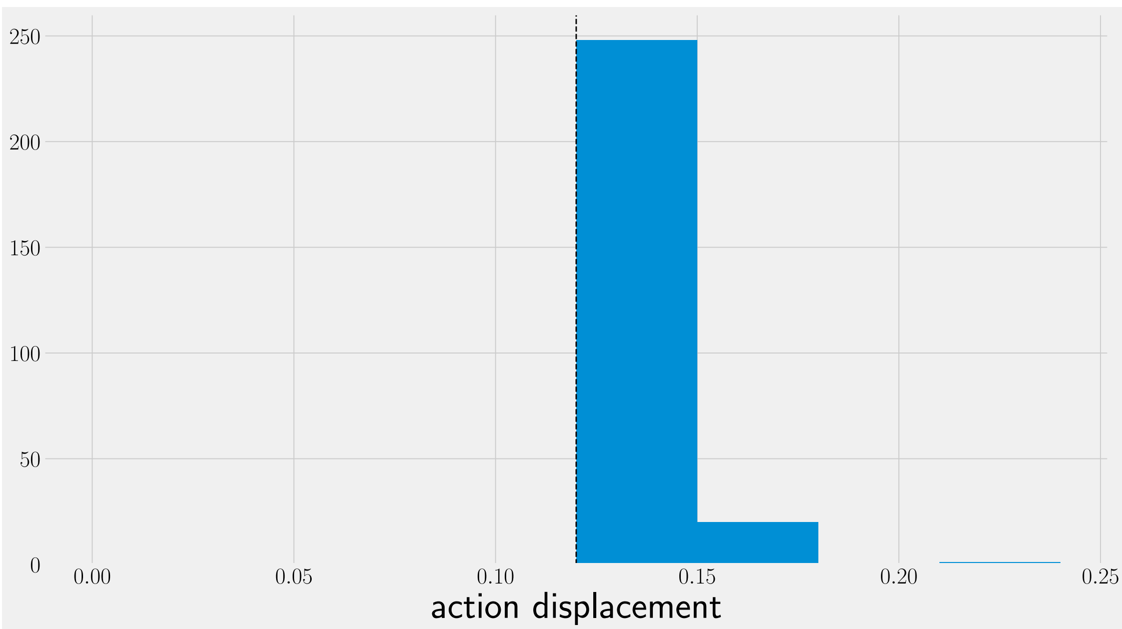

velocity > 0.2 (50%)
slow
fast
velocity > 0.4 (70%)
slow
fast
velocity > 0.7 (90%)
slow
fast
velocity > 0.8 (95%)
slow
fast
90°
135°
45°
180°
0°
225°
315°
270°

[17]:
```
candidate_action = twanalyse.actions([candidate])
```

```
100%|          | 1/1 [00:00<00:00, 3435.14it/s]
```

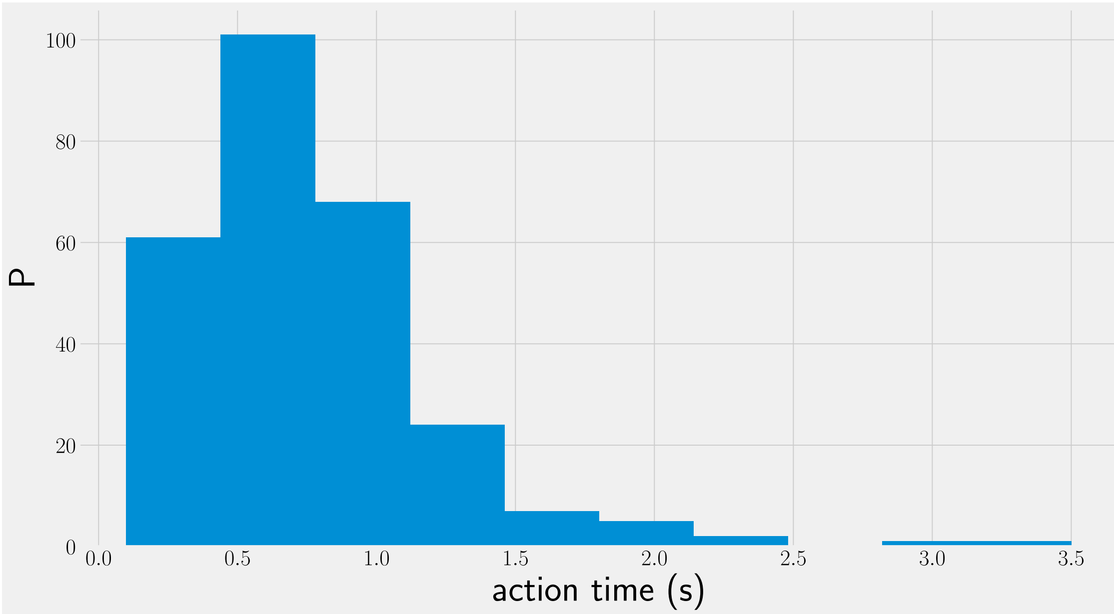
[18]:
```
# plot candidate displacements
ax =plt.gca()
bins = np.arange(0,max(candidate_action['dx']),0.03)
ax.hist(candidate_action['dx'], bins=bins)
ax.set_xlabel('action displacement')
ax.axvline(0.12, linestyle='--', color='k')
```

[18]: <matplotlib.lines.Line2D at 0x7f3934dde760>



[19]:
```
# plot candidate action dt
ax =plt.gca()
ax.set_ylabel('P')
ax.set_xlabel('action time (s)')
ax.hist(candidate_action['dt'])
```

[19]:
```
(array([ 61., 101.,  68.,  24.,   7.,   5.,   2.,   0.,   1.,   1.]),
 array([0.1 , 0.44, 0.78, 1.12, 1.46, 1.8 , 2.14, 2.48, 2.82, 3.16, 3.5 ]),
 <BarContainer object of 10 artists>)
```

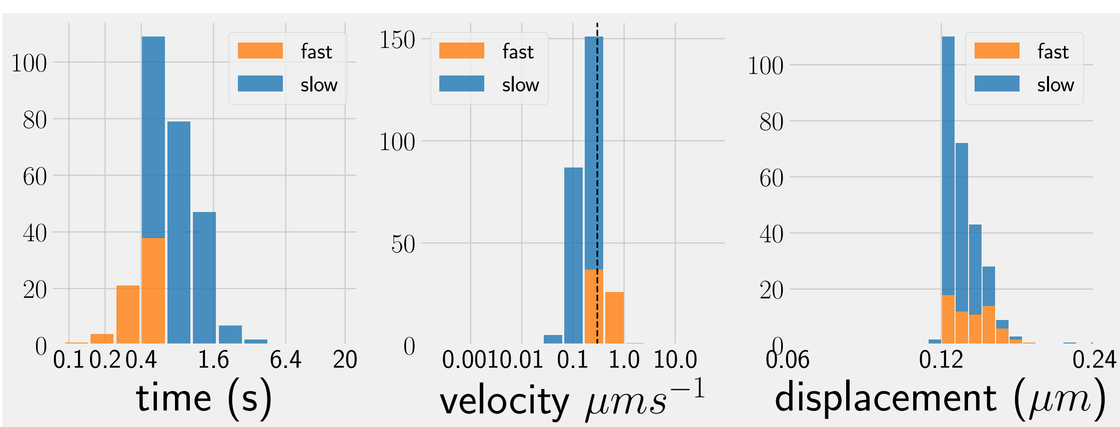



```
[20]: actions = twanalyse.actions
      plot_actiondata = twanalyse.plot_actiondata
      candidate_action = actions([candidate])
      traction = actions(crawling)
```

```
100%|          | 1/1 [00:00<00:00, 3086.32it/s]
100%|          | 2505/2505 [00:00<00:00, 22919.99it/s]
```

```
[21]: plot_actiondata(candidate_action)
      _savefig('candidate_actions.png')
      plt.show()
```

```
trimming 0.0 elements < 0 && 0.0 elements > 100
trimming 0.0 elements < 0 && 0.0 elements > 100
saving to  fanjin/candidate_actions.png
```



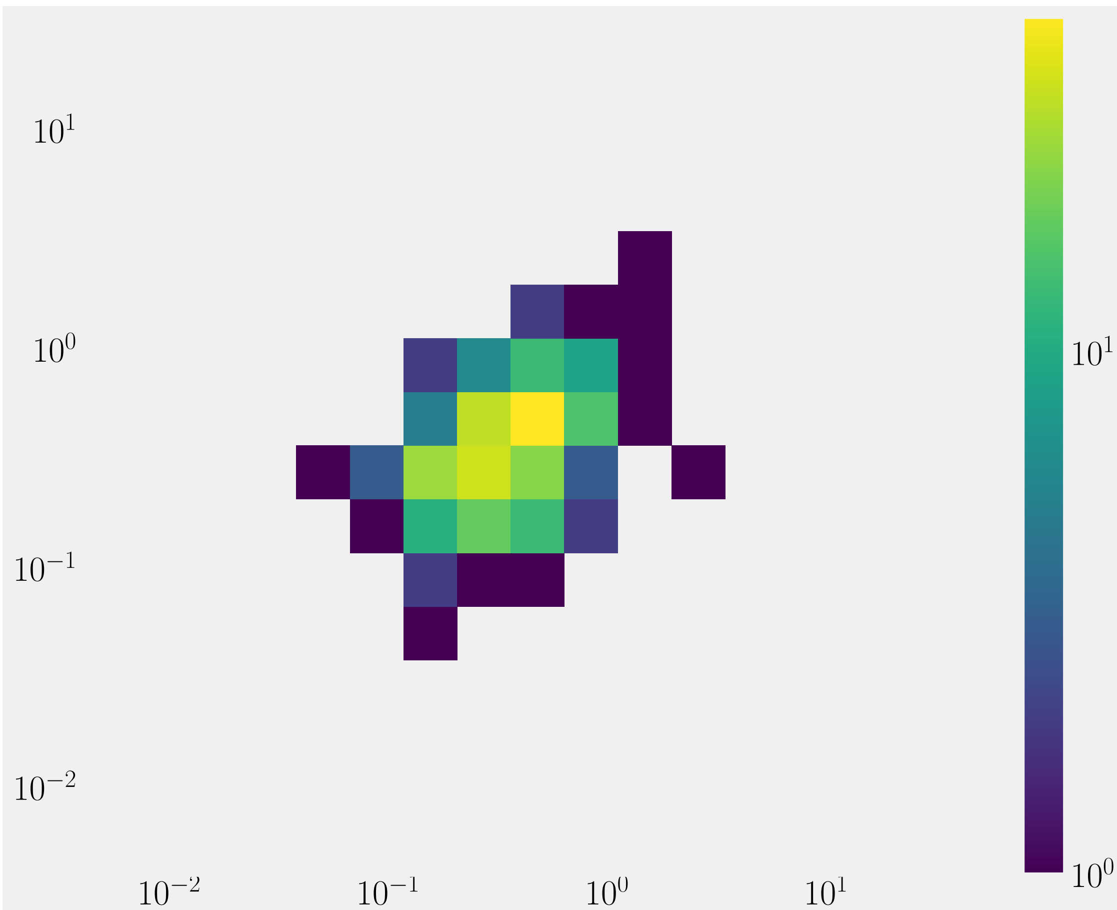
[22]:
```
# all data
if verbose:
        plot_actiondata(traction)
        _savefig('actions.png')
        plt.show()
```

[23]:
```
# [markdown]
# find out where the 0.1/0.2 second fast actions are hiding, look at those␣
↪trajectories by eye.
```

[24]:
```
# plot 2d histogram for actions A,A+1

def action_corr(actions):
        # first bin all the actions but keep track of which bin they belong to
        vel = actions['velocity']
        vel = twanalyse.trim_limits(vel, [0.004,16])
        bins = np.geomspace(0.004,33,16+1,True)
        with np.printoptions(precision=3, suppress=True):
                print('bins', bins)
        bincount = np.zeros(bins.size-1,dtype=int) # one less bin than edge
        binmap = []
        nbin = []
        count2d = np.zeros((bins.size-1,bins.size-1), dtype=int)
        for i in range(vel.size-1):
                v = vel[i]
                v_n = vel[i+1]
                bin_idx = np.searchsorted(bins, v)
                nbin_idx = np.searchsorted(bins, v_n)
                binmap.append(bin_idx)
                nbin.append(nbin_idx)
                bincount[bin_idx] += 1
                count2d[bin_idx][nbin_idx] += 1

        X = bins
        Y = bins
        return X, Y, count2d

X, Y, count2d = action_corr(candidate_action)
def plot_c2d(X, Y, count2d):
        ax = plt.gca()
        ax.set_xscale('log')
        ax.set_yscale('log')
        cmap = mpl.cm.get_cmap()
        cmlist = [cmap(c) for c in np.linspace(0,1,100,True)]
        cm = mpl.colors.LinearSegmentedColormap.from_list('adj', cmlist)
```

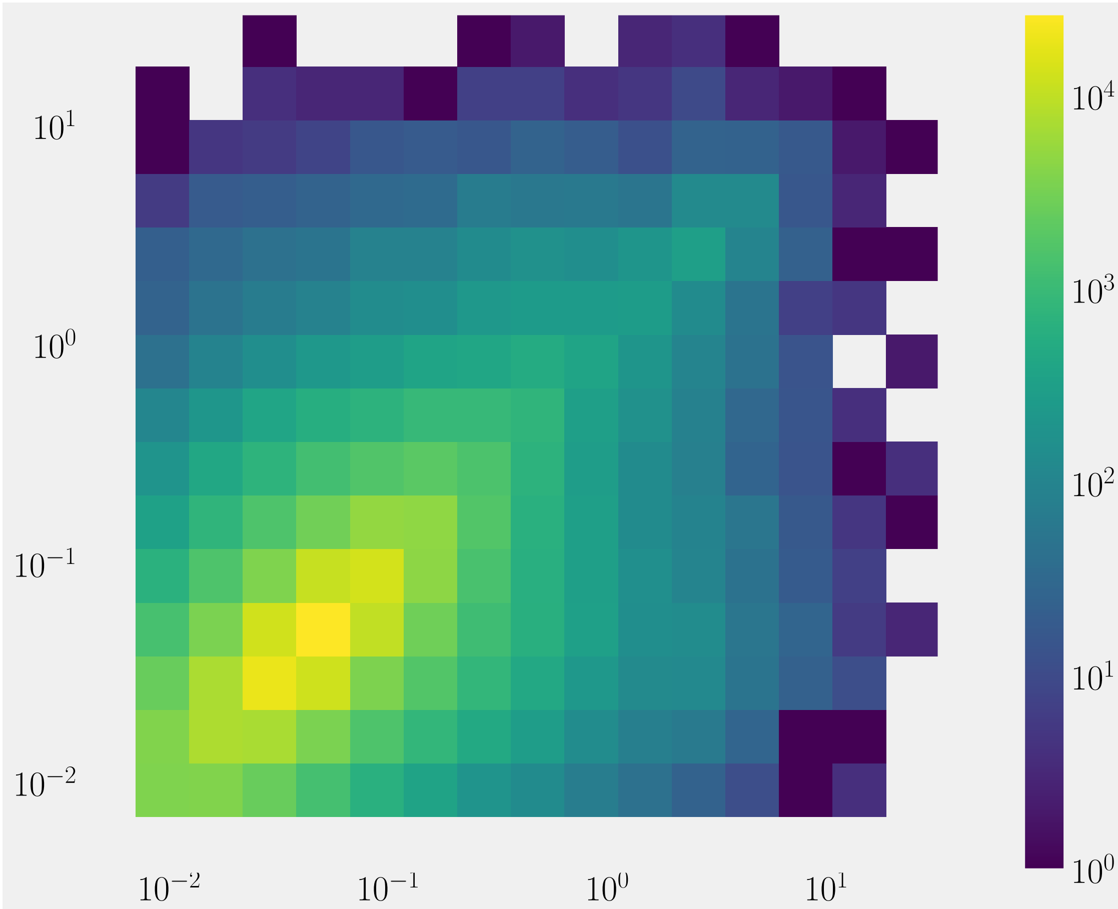
```
        Im = np.ma.masked_where(count2d == 0, count2d)
        # norm = mpl.colors.Normalize(count2d.min(), count2d.max())
        norm = mpl.colors.LogNorm(1.0, count2d.max())
        pos = plt.pcolormesh(X, Y, Im, cmap=cm, norm=norm)
        plt.colorbar(pos)
        ax.set_aspect('equal')
plot_c2d(X, Y, count2d)
```

```
trimming 0.0 elements < 0.004 && 0.0 elements > 16
bins [ 0.004  0.007  0.012  0.022  0.038  0.067  0.118  0.207  0.363  0.638
  1.122  1.971  3.463  6.084 10.689 18.782 33.   ]
```



[25]:
```
X, Y, c2d = action_corr(traction)
plot_c2d(X, Y, c2d)
```

```
trimming 0.04453258316860121 elements < 0.004 && 4.223900518694984e-06 elements
> 16
bins [ 0.004  0.007  0.012  0.022  0.038  0.067  0.118  0.207  0.363  0.638
  1.122  1.971  3.463  6.084 10.689 18.782 33.   ]
```


10^1
10^0
10^{-1}
10^{-2}
10^{-2}
10^{-1}
10^0
10^1
10^4
10^3
10^2
10^1
10^0